

TP 754

. G66





THE
QUANTITATIVE DETERMINATION
OF
AMMONIA AND SULPHUR
IN
COAL GAS.

BY H. W. GILMARTIN.

T P
754
x66

LIBRARY OF CONGRESS.

Chap. Copyright No.

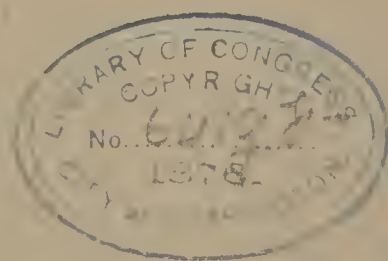
Shelf TP 754
G 66

UNITED STATES OF AMERICA

THE
QUANTITATIVE ESTIMATION
OF
AMMONIA AND SULPHUR
IN
COAL GAS.

BY
WILLIAM W. GOODWIN,

Author of the "History and Principles Involved in the Use of Lowe's Jet
Photometer," and "Methods for Determining the Density and
Specific Gravity of Coal Gas."



PUBLISHED BY WM. W. GOODWIN & CO.,

GAS METER MANUFACTURERS,

*1012, 1014, and 1016 Filbert Street; 1013, 1015,
and 1017 Hunter Street,*

PHILADELPHIA, PA.

1875.

WM. WALLACE GOODWIN,
General Partner.

HOWARD KIRK,
Special Partner.

TP754

Apparatus for Testing for Ammonia in Gas, as illustrated and described in "The Quan- titative Estimation," &c.

Deci-Gallon Mixer (1), Fig. 1, page 12.

Thermometer (1).

Mohr's Burettes (2), mounted on stand, with pinch-cocks
and Erdmann's floats, Fig. 5, page 15.

Pipettes (5), 1 each, 5, 10, 20, 50, and 100 septems (viz.,
35, 70, 140, 350, and 700 grains), Fig. 2, page 12.

Glass Jars (3), Stoppered, $\frac{1}{2}$ gallon.

“ Bottles (4), Stoppered, 20 oz.

“ Funnels (6), 3 inches diameter.

Beakers (6), 4 oz.

Pint Wash-bottle (1), Fig. 3, page 13.

“ Graduate (1).

2 oz. “ (1).

Saturator with Beads (1), mounted on stand, Fig. 6,
page 19.

Meter and Governor (1), Fig. 6, page 19.

CHEMICALS.

$\frac{1}{4}$ lb. Oxalic Acid, pure, crystallized, in stoppered bottle.

1 lb. Ammonia, pure, in stoppered bottle.

1 lb. Sulphuric Acid, pure, in stoppered bottle.

1 oz. Hematoxyline, “ “ “

1 Gallon Distilled Water, pure, in bottle.

STANDARD SOLUTIONS FURNISHED.

(See 3d page of cover for Sulphur Testing Apparatus.)

THE
QUANTITATIVE ESTIMATION
OF
AMMONIA AND SULPHUR
IN
COAL GAS.

BY
WILLIAM W. GOODWIN,
AUTHOR OF THE HISTORY AND PRINCIPLES INVOLVED IN THE USE OF
LOWE'S JET PHOTOMETER, AND METHODS FOR DETERMINING
THE DENSITY AND SPECIFIC GRAVITY OF COAL GAS.

PUBLISHED BY WM. W. GOODWIN & CO.,
GAS METER MANUFACTURERS, 1012, 1014, AND 1016 FILBERT ST.
AND 1013, 1015, AND 1017 HUNTER STREET,
PHILADELPHIA, PA.
1875.

WM. WALLACE GOODWIN,
General Partner.

HOWARD KIRK,
Special Partner.

TP 75A
G 66

Entered according to Act of Congress, in the year 1875, by
W M. W. G O O D W I N,
in the office of the Librarian, at Washington. All rights reserved.

COLLINS, PRINTER.

9-363

P R E F A C E.

THE following little work has been prepared for presentation to our friends and patrons.

The author was prompted to the effort from the fact that there is not, that he is aware of, a single handbook upon the subject published in this country (and but very few in Europe), giving the much coveted information how to determine the *quantity* of sulphur and ammonia in coal-gas. To determine the *fact of its presence* is a very easy matter. However proficient engineers may have been in their knowledge of chemistry when young, few, as they advance in years, and become engaged in the active duties of managing a gas works, can spare the time necessary for retaining such accomplishments; nor are many gifted with a memory so retentive as not to require the aid of written formulæ.

The present work has been written to supply this want; the questions treated have been elucidated in as plain English as possible, removing the haze and mystery that seem to surround them; that which is beyond may be left to the savans. This fact, however, should be remembered: chemistry cannot be understood unless experiment go hand-in-hand with theory—in fact, the theory must be built up by means of inferences drawn from experiments themselves.

In the preparation of the work the author acknowledges his indebtedness to Howard's Practical Chemistry, Sutton's Volumetric Analysis, and Sugg's Gas Manipulation, but

more particularly to Hartley, for the portion directly referring to sulphur and ammonia determinations. In Sugg and Hartley the septem is used as the standard. The author has thought best to introduce the equivalent in grains, as better adapted to the customs of our country, retaining the septem, however, so that in reading the instruments and making tests, either or both systems can be used.

Particular attention is called to "Hints for the Laboratory" and "General Principles," which should be carefully read, and the suggestions contained in them observed in all tests.

Tables are inserted for ascertaining the percentage of sulphur contained in 100 cubic feet of gas (according to Sugg), which will be found of service.

The apparatus, chemicals, and standard solutions referred to, as well as all the apparatus connected with the analysis, measurement, and testing of gas, can be supplied by the author. He trusts the announcement of this fact will not be considered a want of modesty on his part; for one of the principal objects he had in view in preparing these pages was to advertise his business. He is not yet quite beyond the reach of selfish motives. He hopes, therefore, that this honest admission will not cause any loss of *friends* or *patronage*.

WM. W. GOODWIN.

PHILADELPHIA, May 1, 1875.

HINTS FOR THE LABORATORY.

CLEANLINESS is of the utmost importance. Never put away anything dirty. It takes twice the time to cleanse glass vessels when chemicals have dried on them, than it does if washed directly they are done with. Many persons have thrown away bits of dirty apparatus, which they would have looked upon with pride, had they polished them before putting them away.

Do everything and arrange everything in order. Never be in a hurry or flurry. Serious accidents may occur at times through not keeping cool. Have a place for everything, and put everything in its place.

Put all materials and apparatus to be used on your *left* hand before commencing, and move them to your *right* when you have done with them, keeping the middle of your table or bench clear for operating or fitting up. Some arrangement of this kind is absolutely necessary. Do not be wasteful of your materials, although some of them may be cheap. The habit of carefulness in all things cannot be too soon acquired. Bad habits, too, are easily contracted, and are difficult to get rid of; hence as few as possible should be acquired. Look over all preparations required for an experiment before you begin to operate, otherwise you may find the want of something when it is impossible to get it; or you may suddenly discover that you want another hand. It is a good plan to make a list of all apparatus and materials required for the experiments which are to engage the attention. Satisfy yourself beforehand WHY

you do everything, and never be content with making a thing merely do, if it is not done properly. Badly fitted corks, requiring lutes or sealing wax to stop the leaks, must not be suffered at any time. Another should be fitted. Many a serious explosion has occurred for want of these precautions. In all cases use the simplest form of apparatus for an experiment. Unnecessary complications are confusing.

Take careful notes of experiments as they proceed, on paper, or in a rough note-book. Dr. Hofman used to say, "The scrap of paper well stained with acid is of much greater value than the half-worked out, though clean notes, written after the experiment has passed away." The rough notes should be reproduced in a more finished form in a book kept solely for that purpose. The mere copying of scientific facts and formulæ, previously learned in a practical way, is a great help towards remembering them.

Chemical operations should be carried on, if possible, in a room set apart for the purpose. It is better to have it on the ground floor, if possible, as water is more easily obtained, and waste carried off by drains. It should be well ventilated, with a flue in which there is a fire burning, or furnished with a ring of gas-jets, to produce an ascending current. The flue may be furnished with a hood, under which experiments may be performed where noxious vapors arise. A zinc tube about $2\frac{1}{2}$ inches diameter, arranged over the bench, about a foot from the ceiling, with inverted funnel tubes over the gaslights leading into it, can be arranged to produce an upward current, and will keep the room clear. This may be carried into the flue or out of doors. A chamber about 2 ft. by $1\frac{1}{2}$ ft., with glass doors, should be fitted up in every laboratory, however humble, in connection with the flue, in which the experiments with sulphuretted hydrogen, etc., can be carried on. This, however, can be made to lead out of doors also, by having a Bunsen constantly burning, the waste heat being

used for a sand-bath in which evaporations may be carried on, if the chamber be divided by a partition.

The principal sink may be either in the laboratory or just outside, and should be of glazed stoneware to resist acids. A small leaden or japanned iron basin may be let into the bench to carry off waste.

The room should be furnished with a working bench, say 2 feet 6 inches broad, round the wall, and, if necessary, down the centre. A nozzle with a stopcock should be connected with the gas pipe, for attaching the flexible tube; narrow shelves should be fixed along the walls and over the bench to hold the bottles containing *materials* and *reagents*. A cupboard or shelves may be put under the bench, and drawers fitted, to hold the various kinds of apparatus. Water must be at hand in a trough that can be emptied, or in pails.

Of course, where a regular laboratory can be fitted up, further and better means can be adopted than are here suggested; but such arrangements as these will enable a large amount of work to be done.

GENERAL PRINCIPLES.

1. *Quantitative analysis by weight*, or gravimetric analysis, consists in separating the constituents of any compound, either in a pure state or in the form of some new substance of known composition, and *accurately weighing* the products. *Such operations* are frequently very complicated *and occupy a long time*, besides requiring in many cases *elaborate apparatus*, and the exercise of much care and experimental knowledge.

Volumetric processes, on the other hand, are, as a rule, *quickly performed*; in most cases are susceptible of *extreme accuracy*, and *need much simpler apparatus*. The *leading principle* of the method consists in submitting the

substance to be estimated to certain characteristic reactions, employing for such reactions solutions of known strength, and from the volume of solution necessary for the production of such reaction, determining the weight of the substance to be estimated by aid of the known laws of chemical equivalence.

Volumetric analysis, or quantitative chemical analysis by measure, in the case of liquids and solids, consequently depends upon the following conditions for its successful practice:—

1st. A solution of the re-agent or test, the chemical power of which is accurately known, called the “*standard solution*.”

2d. A graduated vessel from which portions of it may be accurately delivered, called the *burette*.

3d. The decomposition which the test solution produces with any given substances *must be of such a character that its termination is unmistakable to the eye*, and thereby the quantity of the substance with which it has combined accurately determined.

The *only* condition on which the volumetric system of analysis can be carried on *successfully* is that the *greatest care* is exercised with respect to the *graduation of the measuring instruments* and the *strength and purity* of the *standard solutions*. A very slight error in the analytical process becomes considerably magnified when calculated for thousands of cubic feet or pounds, hundred weights and tons of the substance tested.

As indicated above, the *end* of the operation in this method of analysis is, in all cases, made apparent to the eye. In alkalimetry it is the change of color produced in hematoxyline, litmus, turmeric, or other sensitive vegetable coloring matter, or the formation of a permanent precipitate, as in chlorine and silver determinations.

In the following pages Mohr's method has been adopted, viz., where the determination of the end of the saturation

of the solution with another is made manifest by the appearance of a *distinct color*, as in dropping acid solutions from a burette into ammonia solution, or *vice versa*.

WEIGHTS AND MEASURES USED IN VOLUMETRIC ANALYSIS.

Instruments for use in volumetric analysis are so graduated that the unit of measurement is the thousandth part of the capacity of the vessel in which the normal or standard test liquors are prepared. Each unit of measurement, therefore, contains the one-thousandth part of the pure chemical substance that is dissolved in the standard measure to prepare any given test liquor.

At the present time three different units of measurement are in use among English chemists.

First. The centimetre cube.

Second. The decem.

Third. The septem.

The septem contains seven English grains of water at 62° Fahr. The test liquors to be used with this measure are prepared in a *deci-gallon*, which contains 1000 septems, and is the tenth part of an imperial gallon, or has the capacity of sixteen fluidounces, or an avoirdupois pound of water. A *burette*, containing one hundred septems, measures the hundredth part of the imperial gallon.

1 septem	=	7 grains	= one division on burette.
10 "	=	70 "	= ten divisions on burette.
100 "	=	700 "	= capacity of burette.
1000 "	=	7000 "	= deci-gallon.
= 1 pound of distilled water at 62° Fahr.			

The following table is inserted for comparison of pounds, gallons, and grains with septems

Gallon.	Deci-Gallons.	Centi-Gallons.	Milli-Gallons.	Septems.	Avoirdupois weight of Water at 62° F.	
					Grains.	Pounds.
1.	10.	100.	1000.	10,000.	70,000.	10.
.1	1.	10.	100.	1,000.	7,000.	1.
.01	.1	1.	10.	100.	700.	.1
.001	.01	.1	1.	10.	70.	.01
.0001	.001	.01	.1	1.	7.	.001

1 Quart = 2500 Septems. 1 Fluidounce = 62.5 Septems.
 1 Pint = 1250 Septems. 1 Cubic Inch = 36.06543 Septems.
 1 Centimetre Cube = 2.2 Septems. 1 Litre = 2.2 Déci-gallons.

THE QUANTITATIVE ESTIMATION OF AMMONIA AND SULPHUR IN COAL GAS.

1.—The preliminary processes by which the quantities of ammonia and of sulphur contained in coal gas are determined, are usually conducted simultaneously, and upon the same volume of gas.

2.—These preliminary processes consist generally, in (1) passing a measured volume of gas slowly through a vessel containing a definite quantity of dilute acid of known strength, which unites with the ammonia, and (2) in afterwards burning the gas in atmospheric air impregnated with ammonia vapors, the products of combustion being condensed and collected in glass vessels.

3.—The after processes consist in the finding (1) the quantity of acid which has entered into combination with the ammonia from the gas, and (2) the weight of baric sulphate precipitated from the condensed products of combustion on the addition of baric chloride.

AMMONIA.

4.—In testing gas quantitatively for ammonia, two solutions* are required, one containing 1 grain of ammonia (NH_3) in 100 measures of the solution, the other containing a little more than 2.88 grains of sulphuric acid (SO_4H_2) in 10 measures of the solution, *i. e.*, such a quantity of acid as will combine completely with and neutralize *one* grain of ammonia.

5.—As both ammonia and sulphuric acid are with difficulty obtained of uniform strength, and as both become

* All the solutions herein mentioned may be obtained of the proper strength from Wm. W. Goodwin & Co.

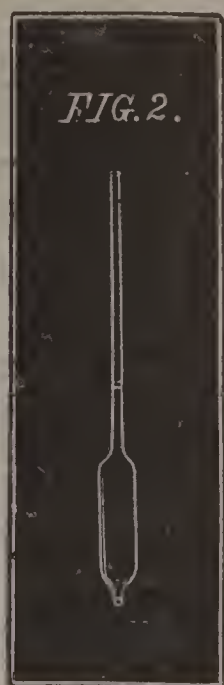
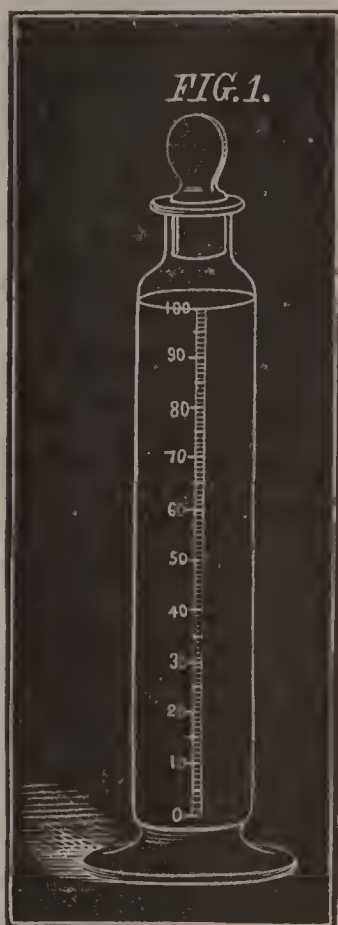
weaker on exposure to the atmosphere, the standard solutions of these compounds cannot be made by diluting samples of unknown gravities by admixture, with a fixed quantity of water; a standard becomes necessary. This is

found in a solution of pure crystallized oxalic acid, an acid of invariable composition $C_2H_2O_4 + 2Aq$. Its combining weight is 126, the weight of two molecules of ammonia being 34. 1 grain of ammonia therefore unites with 3.70588 grains of oxalic acid.

6.—In the making and measuring of the test solutions, the following glass vessels are required: A mixing jar (Fig. 1) graduated into 100 parts (7000 grains), which when charged with any fluid to the 100th line, *while standing on a level base*, measures exactly one-tenth of a gallon of such fluid.

Two burettes (Fig. 5, see page 15) on a wooden stand, S, one of them for use with acid solution, and the other one for use with alkaline solutions. Each burette is graduated into 100 parts (septems, 700 grains). A septem is equal to one ten-thousandth part of a gallon, or to seven grains weight of pure water at 62° Fahr. These burettes are furnished with Mohr's pinchcocks, P, P', Erdmann's floats, E, E', and with funnels F, F'.

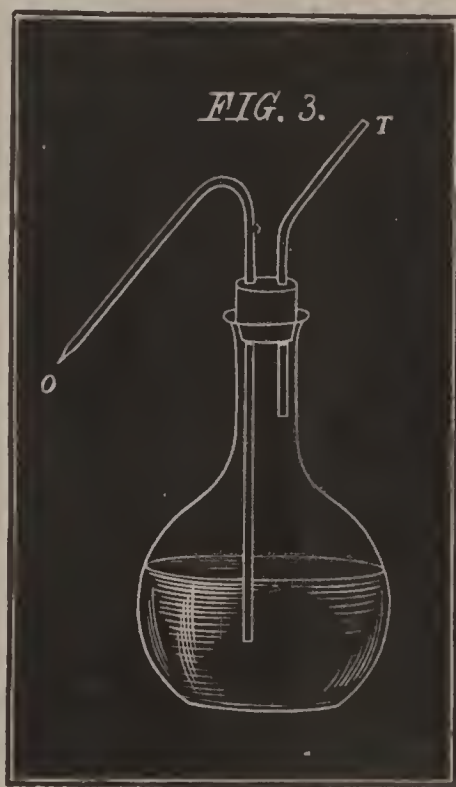
Pipettes (Fig. 2) are also used; these, when properly charged (30) with liquid up to the mark on the stem, measure an exact number of septems. The last drop of fluid must



be delivered by touching the inside of the receiving vessel with the point of the pipette, and at the same time blowing through the latter.

OXALIC ACID SOLUTION.

7.—Weigh in an accurate balance exactly 185.3 grains of pure crystallized oxalic acid, and put this weighed quantity into the clean deci-gallon (7000 grains) mixer. Charge with pure distilled water* to about the 90th graduation. Insert the stopper firmly and shake the mixer at intervals, to assist solution of the crystals, taking care to keep the stopper tightly in the mouth of the mixer. When the solution is complete, dip the *projecting bulb* of a suitable thermometer into the fluid, and if the temperature indicated be 62° Fahr. fill up the mixer to the 100th line with pure distilled water of the same temperature. Wash off the solution from the bulb with distilled water from a wash bottle (Fig. 3), letting the washings fall into the mixer before filling the latter. Owing to capillary attraction, the surface of water contained in cylinders assumes the form of a meniscus, or hollow; it is the lowest point or centre of the meniscus which must coincide with the 100th line on the mixer.



8.—A pipette (Fig. 2) is useful for adding the last few

* Water containing impurities is sometimes sold as "distilled." Try every sample. Add to a portion of it baric solution (55), and to another portion silver solution (57). Both portions should remain clear.

septems of water to the contents of the mixer, and the measurement may be effected to a single drop of water by use of the pipette (6). If the thermometer indicates a temperature above or below 62° , the fluid must be warmed or cooled to the needful extent before it is made up to the 100 measures; that is, if great accuracy be desired. For results closely approximating to truth, a degree or two in temperature will be of no moment.

9.—Transfer the solution from the mixer into a perfectly *clean* and *dry* stoppered bottle, which label thus—

No. 1. *Sol. Oxalic Acid.* 20 septems (140 grains) = one grain Ammonia.

10.—Wash out the mixer with several changes of common water, and finally with two changes of distilled water. Make a second solution of oxalic acid, as above directed. Transfer to a second *clean* and *dry* stoppered bottle, which label—

No. 2. *Sol. Oxalic Acid.* 20 septems* (140 grains) = one grain Ammonia.

11.—Wash out mixer as before (10).

AMMONIA SOLUTION.

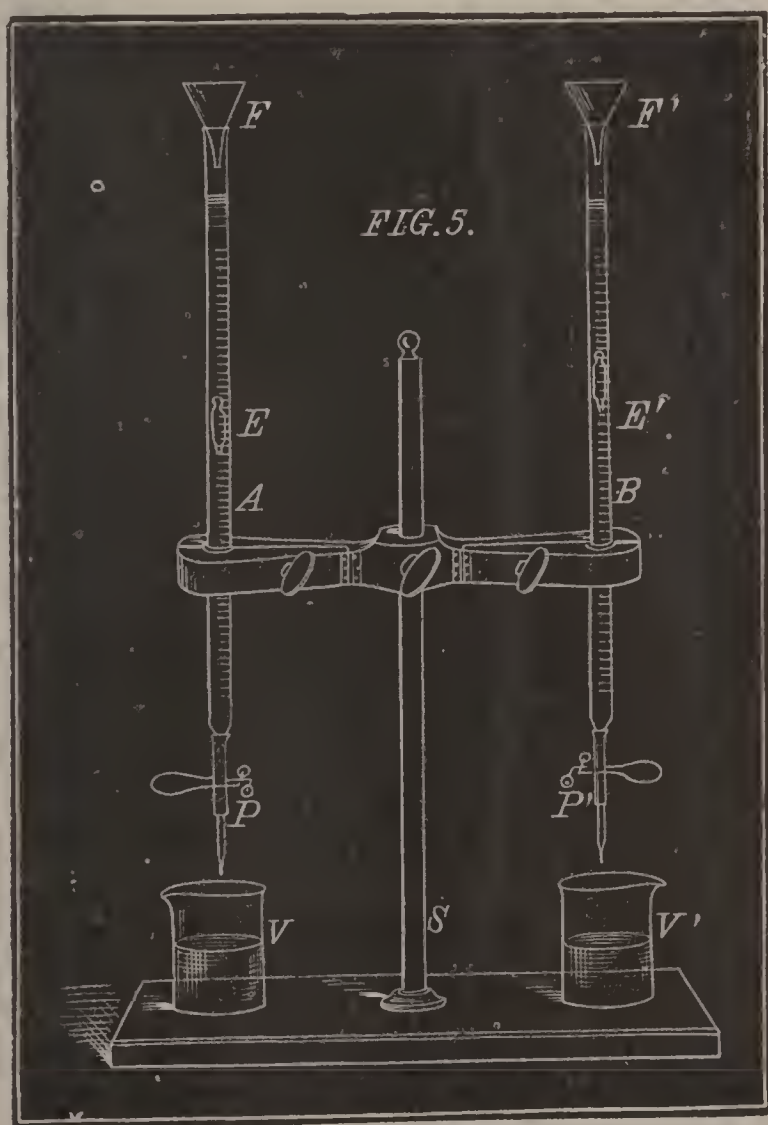


12.—Strong liquor ammonia has usually a gravity of about .88, and contains about 2 grains of absolute ammonia (NH_3) per septem (7 grains). Hence 5 septems (35 grains) to the deci-gallon (7000 grains) should give a solution of nearly the right strength. It is, however, better to proceed as fol-

* Oxalic acid solution will serve as well as the sulphuric (27) for arresting ammonia in the saturator (31); but the oxalic solution, if so employed, should, for convenience, be double the strength of that named above.

lows (5):—hold the 50-septem (350 grains) pipette (Fig. 2) between the fingers and thumb, as shown in Fig. 4.

Moisten the end of the forefinger with the tongue, dip (30) the pipette into the strong ammonia until it is nearly filled. Press the forefinger firmly on the opening at the upper end, and transfer pipette and the contents to the open mouth of a well-stoppered half-gallon glass bottle. Lift the forefinger, and the contents of the pipette will fall into the bottle. Fill up the bottle with pure distilled water at 62° Fahr. Insert the stopper, and shake to insure complete mixture.



13.—Fix the burettes (Fig. 5) perfectly upright, at a convenient elevation on the stand. Pour a few septems of

No. 1 oxalic acid into burette *A*. Place a glass beaker, *V*, below the burette, open the pinchcock, and let the acid flow out. Charge the burette fully with a fresh portion of the acid, and remove the funnel.

14.—Proceed in exactly the same way with burette *B*, using the ammonia solution (12).

15.—Bring the engraved line of each float (6) on a level with the top line on the burette, by opening the pinchcock and letting any excess of solution drop into *V* (13). The points of the glass tubes of the pinchcocks should be slightly greased to prevent the adhesion of drops.

16.—The outside of the burettes must be kept dry; if any solution flow over when charging them, the outside must be carefully wiped.

17.—Place a perfectly clean glass beaker, similar to *V* (Fig. 5), below the burette *A*, and let fall into the vessel exactly 10 septems (70 grains) of acid solution, which color with two or three drops of solution of hematoxyline. Into the same vessel let fall from *B*, sufficient of the ammonia solution to change the color of the liquid from yellow to pink. The last additions must be made in single drops, and the mixture well stirred between each addition with a glass stirrer.

18.—When the change of color is effected, note how many septems of ammonia solution have been used. Assume the number to be 30 (210 grains). To the mixture add 10 more septems (70 grains) from *A*, and two more drops of hematoxyline. Recharge (15) *B* with ammonia solution (12), and deliver from it as much as will again change the color of the mixture in a beaker to pink. Assume it, as before, to be 30 septems (210 grains). In such case, 60 septems (420 grains) of the ammonia solution would contain one grain of ammonia (9). These trials should be repeated, using No. 2 oxalic acid. If the results differ from those obtained

with No. 1 acid, one or both acid solutions must be wrong, and fresh solutions must be more carefully made.

19.—The solution of ammonia (12), if kept in a cool place and in a well-stoppered bottle, will serve as a stock from which at any time to make the standard solution in a few minutes. The bottle should be labelled, and the strength of the solution indicated on the label—

Sol. Ammonia. 60 septems (420 grains) contain 1 grain
 NH_3 .

TO MAKE THE STANDARD AMMONIA SOLUTION.

20.—Put as many *parts* of the stock ammonia (12) (19) into the deci-gallon (7000 grains) mixer as *septems* of the ammonia solution were used to saturate 20 septems (140 grains) of the oxalic solution (9), and make up with distilled water to 100 measures (8). Whenever a standard solution is made, it should be determined, as described in paragraphs 13 to 18, that 100 septems (700 grains) of it neutralize 20 septems (140 grains) of the oxalic solution.

21.—Put the standard solution into a clean, dry, and well-stoppered bottle, and label—

Sol. Ammonia. 100 septems (700 grains) contain 1 grain
 NH_3 .

SULPHURIC ACID SOLUTION.

22.—The gravity of pure strong acid is 1.848, its composition SO_4H_2 , and its combining weight 98. The weight of two molecules of ammonia is 34. So that 2.8824 grains of the acid are required to combine with one grain of ammonia. One septem (7 grains) of such acid weighs 12.922 grains; consequently nearly 23 septems (161 grains) of it are required in the deci-gallon (7000 grains) of dilute acid of ten times the equivalence of the standard ammonia solution (5).

23.—Half fill a well-stoppered half-gallon glass bottle with pure distilled water. Insert a funnel in the mouth of the bottle, and gently pour in one and a quarter or one and a half measured ounces of strong sulphuric acid. Shake (7). Fill up the bottle with distilled water. Cover the mouth, or insert the stopper *loosely*, and allow the bottle to stand in a cool place until the temperature is found, on applying a thermometer (7), to be reduced to 62° Fahr. (8).

24.—Wash well the burette A inside and out, pinch-cock, float, etc. (10). Half fill it with the dilute sulphuric acid, and then empty it (13). Fully charge with the sulphuric acid (13), and charge B with standard ammonia solution (14). Adjust the liquids to the proper heights (15).

25.—Proceed as described in paragraphs 17 and 18, using *five* septems (35 grains) only of the acid each time, and continuing the test until at least 25 septems (175 grains) of the acid have been acted on in the beaker. The burette B will, of course, need filling several times. Suppose it be found that 120 septems (840 grains) of the ammonia solution are required to saturate 10 septems (70 grains) of the acid. $120 : 100 :: 10 : 8.333$ —*i.e.* 8.333 septems (58.333 grains) of the acid are sufficient to neutralize 100 septems (700 grains) of ammonia solution. The acid solution (23) may be kept as described in paragraph 19, and should be labelled—

Sulphuric Acid. 8.333 septems saturate one grain Ammonia, or 83.33 parts to a deci-gallon.

TO MAKE THE STANDARD SULPHURIC ACID SOLUTION.

26.—Put ten times as many parts of the stock acid (23) into the deci-gallon mixer (7000 grains) as septems of the acid are required to saturate 100 septems (700 grains) of the standard ammonia solution, and make up to 100 measures (8). 83.33 measures of acid of the above strength would require to be made up to 100. Whenever a standard solu-

tion of acid is made, it should be determined—as described in paragraphs 13 to 18—that 10 septems (70 grains) of it exactly neutralize 100 septems (700 grains) of standard ammonia solution.

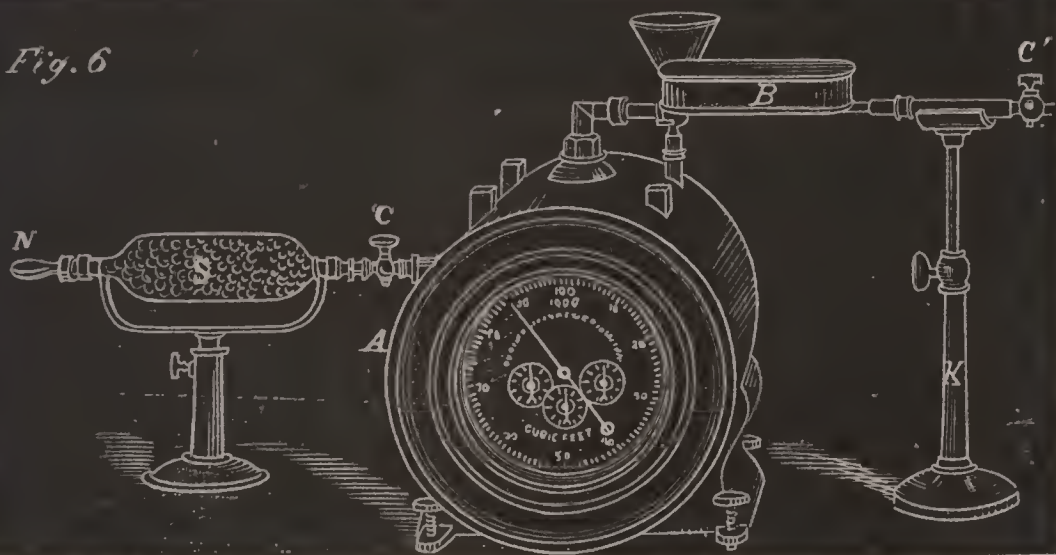
27.—Decant the solution into a stoppered bottle and label—

Sol. Sulph. Acid. 10 septems (70 grains) saturate one grain Ammonia, and = 100 septems (700 grains) NH_3 sol.

28.—In addition to the before-mentioned apparatus, the following are required:—

1st. An ammonia saturator, S (Fig. 6), which is a glass vessel filled with glass beads having a movable nose-piece, N, at one end, and a cock, C, at the other. The saturator is supported in a horizontal position by a stand.

Fig. 6



2d. An experimental meter, A, with index showing the hourly rate of measurement by one minute's observation, and indicating up to one hundred cubic feet.

The meter shown in the figure can be made, if desired, capable of automatically stopping the flow of gas when 10 cubic feet have been measured.

3d. A governor, B, to maintain a uniform rate of delivery of gas from the meter. The governor is a dry one, and is,

for convenience, placed on the top of the meter. The outlet tube terminates with a cock, C'.

TO SET THE APPARATUS TO WORK.

29.—Remove the saturator (Fig. 6) from its stand, take out the nose-piece N, and close the cock C.

30.—Charge the burette A (13) with sufficient of the dilute acid (27), or, take a pipette (Fig. 2) of the requisite size and dip its *point* into the acid, apply the lips to the upper end and suck up the acid* until it rises to a little above the mark on the stem. Cease to suck, and immediately press the moistened finger on the top (12). The pipette can be properly charged only in this way when used as a measure, as its exterior must be kept dry. Hold the pipette before the eyes, and by partly raising the forefinger allow any excess of acid to drop from the point, until the centre of the curved surface of the liquid coincides with the mark on the stem.

31.—Charge the saturator, either by means of the burette or the pipette (6), with dilute acid (27); the quantity may be about *one septem* (7 grains) or *two septems* (14 grains) of acid to *each cubic foot of gas* which it is intended to pass through the saturator (33), but must be sufficient to thoroughly wet the beads.

32.—Place the saturator on its stand, Fig. 6, insert the nose-piece, N, which connect by means of a few inches of

* Caution must be used in filling the pipette with poisonous solutions, such as oxalic acid, in order to avoid their entry into the mouth. The point of the pipette must be kept well immersed while sucking. Strong ammonia, strong acids, and all kinds of fluids which give off fumes of a poisonous or irritating character must not be sucked into the pipettes in the way described.

flexible tube to the gas supply cock.* Connect the other end of the saturator in a similar way to the inlet of the meter.

33.—Set the meter index to zero, or take the index, turn on the gas, and adjust, by means of the governor on the outlet of the meter, the rate of flow, to from one-half to one cubic foot of gas per hour, according to circumstances (41–42). Leave in operation for say 20 hours, or until at least ten cubic feet of gas have been passed through the saturator.

TESTING OPERATIONS.

34.—When sufficient gas has been operated upon, say ten cubic feet, cut off the supply, close the cock, C, of the saturator, raise it from its stand, remove the nose-piece, N, and hold the saturator, cock downwards, over a graduated glass measure; open the cock and let the acid run into the measure. Pour distilled water through the saturator into the measure until, on the application of a litmus test-paper to the dropping fluid, it is found to produce no discoloration of the paper. From 9 to 18 oz. of water will be needed. Make up the quantity to 10 or 20 oz.

35.—Measure into a glass vessel (17) exactly one-tenth of the liquid, and render it of a light yellow color by the addition of hematoxyline solution. Charge the burette, B, with ammonia solution (21). Adjust the fluid to the proper height (15), and then discharge into the acid contained in the beaker sufficient of the ammonia solution to change the color of the liquid to pink. Suppose 10 cubic feet of gas have acted upon 20 septems (140 grains) of acid

* The gas passes through the saturator before being measured, in order to avoid the possibility of the absorption of any of the ammonia by the water in the meter.

in the saturator. Each septem (7 grains) of acid solution is *neutralized* by 0.1 grain of ammonia.

Each septem (7 grains) of ammonia

solution *contains* 0.01 “ “

One-tenth of the acid used, or 2 septems

(14 grains), requires of ammonia

. 0.2 grain.

After exposure to the gas, it requires

of ammonia solution 18.2 septems

(127.4 grains), which contain of

ammonia 0.182 “

Ammonia in the gas per cubic foot 0.018 “

Ammonia per 100 cubic feet . . . 1.8 “

Suppose 22 cubic feet of gas have acted upon 50 septems (350 grains) of acid in the saturator.

One-tenth of the acid used, or 5 septems (35

grains), requires of ammonia 0.5 grain.

After exposure to the gas, it requires of ammonia

solution 45.4 septems (317.8 grains),

which contain of ammonia 0.454 “

Ammonia per 2.2 cubic feet 0.046

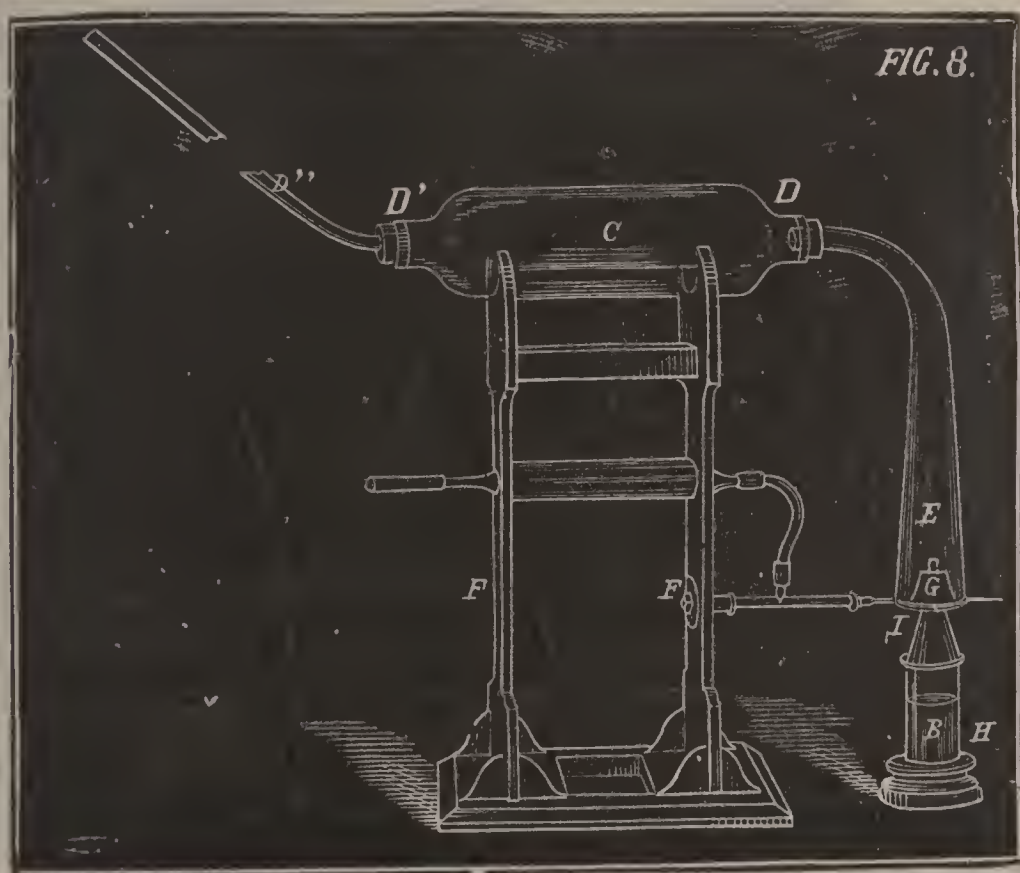
2.2 : 100 :: 0.046 : 2.09 grains per 100 cubic feet.

If any question is likely to arise as to the correctness of the results, it is advisable to preserve for a week one-half of the liquid (34) in a stoppered bottle, labelled and dated, and to operate on one-fifth of the remaining liquid. It is well to repeat the test on a second portion of the liquid.*

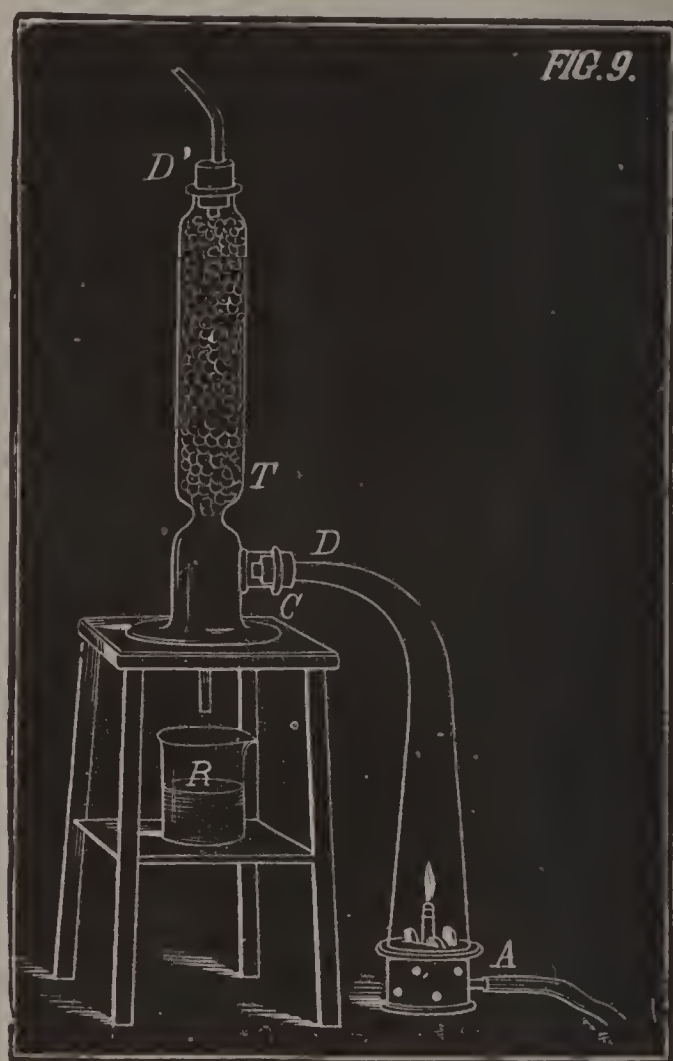
* If the flexible tube of the burettes is kept some time in compression by the pinchcocks it is apt to become *set* and permanently closed. It is therefore advisable, when the burettes are not to be used for several days, to remove the pinchcocks. Pure black rubber tube is used, the ordinary vulcanized tube not being suitable.

SULPHUR.

36.—Various apparatus have been invented and employed in which to burn the gas, and to condense and collect the products of combustion (2). The apparatus most



employed are represented in Figs. 7, 8, and 9. Fig. 7 represents the original instrument devised and introduced by the late Mr. Alex. Wright. Fig. 8, Dr. Letheby's instrument; and Fig. 9, the Referee's Apparatus, which is

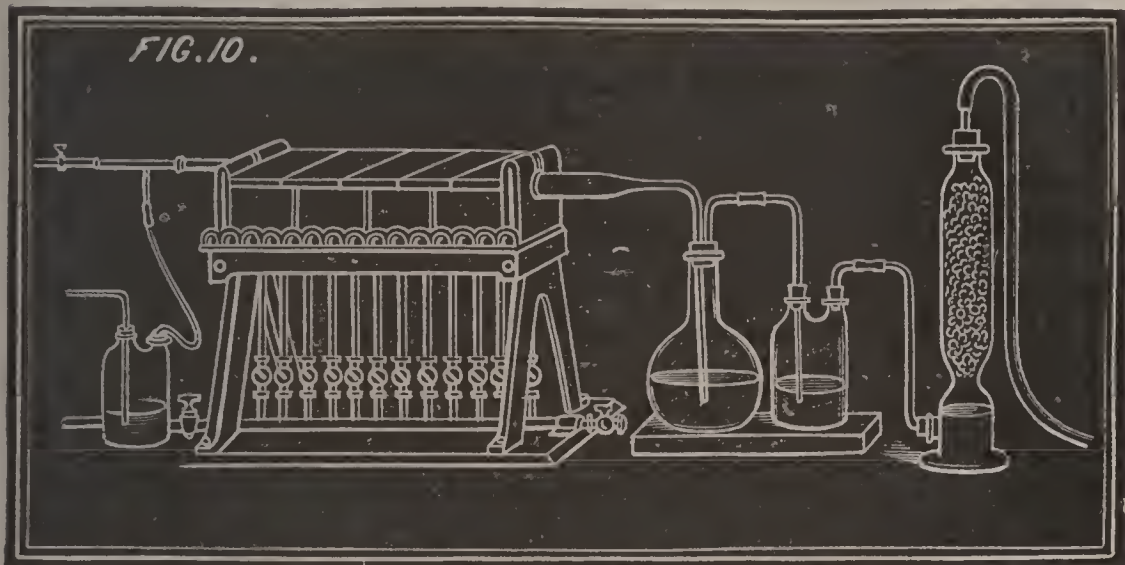


now used in London. Fig. 10 is an admirable apparatus, proposed by W. Valentin, Esq., of the Royal College of Chemistry, but which has not yet been much applied in commercial testing.

37.—The analysis of the products arising from the combustion of equal volumes of the same gas, in these several instruments, indicates different quantities of sulphur in the gas. The products from Wright's indicate the least quantity, from Dr. Letheby's and the Referee's Apparatus more

than those from Wright's, while it is supposed that the products from Mr. Valentine's apparatus indicate the entire quantity of sulphur contained in the gas burned.

FIG. 10.



38.—In order to obtain results with each instrument which shall be comparable and as exact as possible, it is necessary to use each instrument under the same conditions, in a room not subject to vibrations, free from draughts, and of uniform temperature, and in an atmosphere free from sulphur vapors.

39.—It is therefore indispensable that the gas be burned at a uniform rate on all occasions, that the flames be steady, that the products be condensed under the same temperature, and that no sulphur vapors be produced in the room by the ignition of lucifer matches, etc., and that any gas flames which may be employed for lighting shall be ventilated—that is, have the products of their combustion conveyed out of the room as fast as they are produced:

TO SET THE APPARATUS TO WORK.

40.—Remove the vessel B, and the chimney E (Figs. 7 and 8), and charge B with two fluidounces of strong *fresh* ammonia (the ammonia, or any part of it, must never be used a second time in the apparatus). Restore B to its position, taking care, with the Letheby apparatus, that the pipe of the funnel which is inverted over B rises through the centre of the burner to the height of one inch above the top of the burner tubes, that the junctions, D D', are quite sound, and that the outlet tube, D'', enters the condenser at such an angle that any fluid condensed in the tube may fall into the condenser. Connect the burner of B (Fig. 7), or the burner of the Letheby apparatus (Fig. 8), by means of a short piece of flexible or other tube to the outlet of a governor attached to an experimental meter (32-33).

41.—Turn on the gas, ignite it at the burner above B, and adjust the rate of consumption, by the aid of the governor (33), to (1) *half a cubic foot* per hour with *Wright's* and (2) *one cubic foot* per hour with Letheby's apparatus. Set the meter index to zero, and instantly replace the chimney, E. Let the apparatus continue in action for from 20 to 24 hours, or until at least ten cubic feet of gas have been burned (33-28).

42.—The Referee's apparatus (Fig. 9) is set to work in a similar manner, the rate being *half a cubic foot* per hour; but the Referees recommend the use of carbonate of ammonia in the place of liquid ammonia. The lumps of carbonate are placed round the burner, as at A. The junctions at D D' are made with India-rubber tubing, the top of the chimney, C, being pressed closely against the neck at the bottom of the glass tower, T, which is filled with glass balls. The liquid products of combustion with the appa-

ratus, Figs. 7 and 9, fall into the receiver, R, while with Letheby's apparatus they collect in the condenser, C.

43.—It is usual with Wright's apparatus to allow a gentle stream of water to flow in at the funnel and through the condenser, so as to maintain the temperature at about 80° Fahr.

44.—If the ammonia saturator (28) is to be used simultaneously with the sulphur test, a stop-cock should be fixed in the pipe connecting the governor to the burner of the sulphur test C' (Fig. 6), and before passing the gas for an analytical test, the rate should be adjusted in the following way. Charge (30) the saturator with as many septems of water as it is intended to charge it with acid. Place it on its stand, and carry the gas supply from it through the meter and governor to the sulphur-test burner. Adjust the rate of the flow by means of the governor (33). Close the stop-cock above mentioned, C' (Fig. 6), and also the supply-cock (32). Set the meter index at zero. Disconnect, remove, and well wash out the saturator with distilled water, and charge it with acid (31). Refix in position for use, and turn on the supply-cock. Open the stop-cock, C' (Fig. 6), on the tube between the governor and the sulphur test burner, light the gas, and replace the parts of the apparatus as directed (41). If the governor be once carefully adjusted, it will need little or no alteration afterwards.

45.—As the meter and governor must be entirely free from air before the gas is burned in the sulphur-test, it is advisable to have a duplicate supply-pipe, provided with a stop-cock, on the meter inlet. On closing the cock, C (28), of the saturator, gas may be passed from the duplicate supply-pipe, through the meter, and be allowed to escape at C' (Fig. 6), so as to expel the air from the meter whenever it becomes needful to do so.

46.—As Mr. Valentine's apparatus (Fig. 10) is not in ordinary use, it will be sufficient to say that it consists of a platinum or porcelain combustion tube, a gas furnace, the vessels shown in the wood-cut, and an aspirator. The platinum combustion-tube is filled partly with a platinum wire cage, charged with spongy platinum and partly with soda lime (made by slaking pure lime with a solution in distilled water of pure caustic soda). The tube is then placed in the gas furnace, and maintained at a high temperature, while a measured volume of gas, mixed with a due proportion of air, is sucked, as it were, by means of the aspirator, through the combustion tube. The mixture of gas and air burns when in contact with the spongy platinum, and the products pass through the soda-lime, which absorbs every atom of the sulphuric acid generated by the combustion of the sulphur in the gas. The porcelain tube contains only a cage of spongy platinum, the products being drawn through a solution of soda-lime contained in a glass flask, whereby the sulphuric acid is absorbed. The soda-lime used in the platinum tube is taken out and dissolved in dilute hydrochloric acid, or, if the porcelain tube be used, the soda-lime solution is acidulated with dilute hydrochloric acid. The after processes are the same as those which will now be described.

47.—As already mentioned, various apparatus have been designed for sulphur testing. Those mentioned herein are of a simple character.

TESTING OPERATIONS.

48.—If Wright's apparatus (Fig. 7) be employed, pour the liquid from the receiver, R, into a graduated glass measure, wash out the receiver with distilled water (note, paragraph 7), which add to the contents of the measure.

49.—If the Letheby apparatus (Fig. 8) be used, remove the chimney, E, and the outlet tube. Empty the contents of the condenser into a graduated glass measure. With distilled water wash well the interior of the condenser, the chimney, and the outlet tube, and add the washings to the contents of the measure.

50.—If the Referee's apparatus (Fig. 9) be used, pour the collected fluid from R into a graduated glass measure; wash T (by pouring distilled water through it), the receiver, the chimney, and the outlet tube. Add the washings to the contents of the glass measure.

51.—In every case make up with distilled water the contents of the measure to an easily dividable quantity, say 16 to 20 ounces.

52.—Transfer *exactly one-half* of the liquid from the measure to a glass flask, F, which place over a Bunsen burner, Fig. 11, or in a sand-bath, and boil for five minutes.*

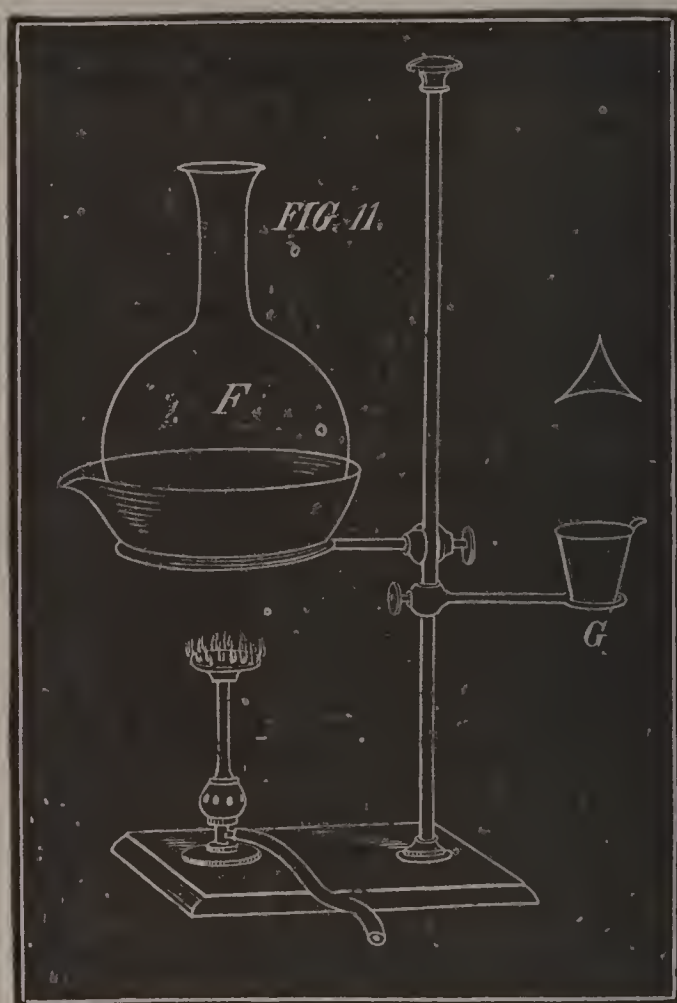
53.—The other half of the liquid may be afterwards operated upon, or stored in a stoppered bottle, labelled and dated, for testing, if needful, at a future time (35).

54.—Add to the contents of the flask (52), and while doing this gently shake the flask to insure complete mixture, some pure dilute hydrochloric acid (one part acid to eight or ten parts of distilled water) in sufficient quantity to render the liquid *acid*, *i. e.*, capable of reddening a blue litmus paper. Add also a drop of strong nitric acid or of bromine, by means of a small pipette (Fig. 4).

55.—Boil some distilled water in a flask, as in Fig. 11, and add to it a small quantity of baric chloride. Add a

* If the glass vessels be exposed directly over the flame, use a rose-head on the Bunsen burner, and take care that the flames do not touch the vessel, otherwise it is likely to break.

small portion of the baric solution while still hot to the acidulated liquid (54) and boil the latter for a minute or



so. Repeat this process until it is observed that the added drops of baric solution produce no additional milkiness in the liquid. Boil for a few minutes more, and then set the flask (F) and its contents aside to cool. A white precipitate should fall and leave the liquid quite clear. Decant as much of the clear liquid as it is possible to remove without carrying off *a particle* of the powder.

56.—Fold a small filter paper* and place it in the glass funnel F (Fig. 12). Apply the mouth to the tube T of a

* The paper must be free from impurities; when burned by itself in the crucible to whiteness, the ash should not weigh more than the $\frac{4}{100}$ of a grain (59).

wash bottle (Fig. 3) containing distilled water, and blow a gentle stream of water from O upon the paper so as to



thoroughly wet it. Shake the contents of F (52, 55), and pour them upon the filter, taking care that the fluid does not overrun the edge of the paper. Wash the flask several times with small quantities of distilled water, and pour the washings on to the filter so as to collect thereon every particle of the precipitate from the flask.

57.—Blow upon the filter from a wash-bottle (56) a gentle stream of *boiling*, or very hot, distilled water, in order to free the filter from soluble salt (64). The washing is complete if a drop of the fluid from the tube of the funnel produces no cloudiness when let fall into a little nitrate of silver solution contained in a test-tube or small glass vessel. To make the silver solution, dissolve about

five grains of the nitrate in an ounce of distilled water, and keep in a stoppered bottle.

58.—When the filter is sufficiently drained from water place the funnel on a filter dryer, and set the whole on a hot plate or sand-bath.

59.—When quite dry remove the filter from the funnel. Place a platinum crucible, G (Fig. 11), the weight of which has been accurately determined in a sensitive balance and recorded, upon a sheet of clean, smooth, and if possible *dark* colored, paper. Hold the filter over the crucible and unfold it. Bring the edges of the filter paper together so as to form a sort of bag with the powder inside. With a gentle rolling action move the top of the bag to and fro. The powder will become detached from the paper and must be transferred as completely as possible to the crucible. Refold the filter into a small parcel, tie round with a thin platinum wire, ignite, and let the ashes fall into the crucible. Transfer any spilled particles of the powder to the crucible. Heat the crucible for some minutes in the flame of a Bunsen burner, from which the rose-head has been removed (Fig. 11).

60.—When the crucible is cold, reweigh it; the difference between this weight and the previously recorded weight will be the weight of the contained powder, which is baric sulphate.

61.—233 parts by weight of baric sulphate contain 32 parts of sulphur $\frac{32}{233} = .13734$.

Rule. Multiply *twice* the weight (52) of the powder by the reciprocal .13734, the product will be the weight of the sulphur which was contained in the gas burned (41, 42).

Suppose *twice* the weight of the sulphate obtained be 14 grains: $14 \times .13734 = 1.92276$ grains of sulphur. If the quantity of gas be 10 cubic feet, this gives 19.2276 grains of sulphur per 100 feet.

Suppose twice the weight of the sulphate obtained be 29.8 grains : $29.8 \times .13734 = 4.0927$. If the quantity of gas be, say, 22 cubic feet, then—

22 c. ft. : 100 c. ft. :: 4.0927 grains : 18.603 grains sulphur per 100 c. ft.

62.—When the utmost exactness is desired, it is requisite to place the crucible, while still hot, over a vessel containing strong sulphuric acid, and to cover the whole with a glass bell. The affinity of the acid for moisture preserves the powder absolutely dry. When cold, the weighing operations must be conducted with great promptitude, and in a dry place. Better if in a lantern balance, in which has been previously placed a vessel containing strong sulphuric acid.

63.—The chemical reactions upon which the analysis for sulphur, as described, depends, are as follows:—

Gas contains *hydrogen*, *carbon*, and *sulphur*, which in the process of combustion combine with the oxygen of the atmosphere, and form *water*, *carbonic acid*, and *sulphurous acid*; the last being speedily oxidized more or less completely into *sulphuric acid*. *Ammonia* being present (2), the acids unite with it, *ammonic carbonate* and *sulphate* being formed, which are thrown down in a solution with the condensed *water of combustion*.

64.—*Baric chloride* decomposes both *ammonic carbonate* and *ammonic sulphate*, the acids of those salts uniting with the *barium* of the *chloride* to form *baric carbonate* and *baric sulphate*, while the *chloride* of the baric chloride unites with the *ammonia* of the ammonic carbonate and sulphate to form soluble *ammonic chloride*. In order to avoid the precipitation of *baric carbonate* with the *baric sulphate* (55), the liquid is first boiled to expel any carbonic acid and the greater part of the *ammonic carbonate*. *Hydrochloric acid* is next added to (54) decompose the remaining carbonate, the *chlorine* of the acid combining with

the ammonia to form a soluble salt, *ammonic chloride*, which is unaffected by barium. The drop of nitric acid or of bromine is added for the purpose of oxidizing into sulphuric acid any sulphurous acid which may be held in solution. The liquid is again boiled, to expel carbonic acid. Finally, the baric solution is used to decompose the ammonic sulphate, and give a precipitate of insoluble baric sulphate.

65.—All the chemicals employed must be of the purest description. If it is deemed needful to test any samples, the requisite information will be found in chemical text books.

The following tables from Sugg's Gas Manipulation are inserted for ascertaining the percentage of sulphur :—

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
10	1.355	2.711	4.067	5.423	6.779	8.135	9.491	10.847	12.203	13.559	14.915	16.271	17.627	18.983
11	1.232	2.465	3.697	4.930	6.163	7.395	8.628	9.861	11.093	12.326	13.559	14.791	16.024	17.257
12	1.129	2.259	3.389	4.519	5.649	6.779	7.909	9.039	10.169	11.299	12.429	13.559	14.689	15.819
13	1.043	2.086	3.129	4.172	5.215	6.258	7.301	8.344	9.387	10.430	11.473	12.516	13.559	14.602
14	.968	1.937	2.905	3.874	4.842	5.811	6.779	7.748	8.716	9.685	10.653	11.622	12.590	13.559
15	.903	1.807	2.711	3.615	4.519	5.423	6.327	7.231	8.135	9.039	9.943	10.847	11.751	12.655
16	.847	1.694	2.542	3.389	4.237	5.084	5.932	6.779	7.627	8.474	9.322	10.169	11.016	11.864
17	.797	1.595	2.392	3.190	3.988	4.785	5.583	6.380	7.178	7.976	8.773	9.571	10.368	11.166
18	.753	1.506	2.259	3.013	3.766	4.519	5.273	6.026	6.779	7.532	8.286	9.039	9.792	10.546
19	.713	1.427	2.140	2.854	3.568	4.281	4.995	5.709	6.422	7.136	7.850	8.563	9.277	9.991
20	.677	1.355	2.033	2.711	3.389	4.067	4.745	5.423	6.101	6.779	7.457	8.135	8.813	9.491
21	.645	1.291	1.937	2.582	3.228	3.874	4.519	5.165	5.811	6.456	7.102	7.748	8.393	9.039
22	.616	1.232	1.848	2.465	3.081	3.697	4.314	4.930	5.546	6.163	6.779	7.395	8.012	8.628
23	.589	1.179	1.768	2.358	2.947	3.537	4.126	4.716	5.305	5.895	6.484	7.074	7.663	8.253
24	.564	1.129	1.694	2.259	2.824	3.389	3.954	4.519	5.084	5.649	6.214	6.779	7.344	7.909
25	.542	1.084	1.627	2.169	2.711	3.254	3.796	4.338	4.881	5.423	5.966	6.508	7.050	7.593
26	.521	1.043	1.564	2.086	2.607	3.129	3.650	4.172	4.693	5.215	5.736	6.258	6.779	7.301
27	.502	1.004	1.506	2.008	2.510	3.013	3.515	4.017	4.519	5.021	5.524	6.026	6.528	7.030
28	.484	.968	1.452	1.937	2.421	2.905	3.389	3.874	4.358	4.842	5.326	5.811	6.295	6.779
29	.467	.935	1.402	1.870	2.337	2.805	3.272	3.740	4.208	4.675	5.143	5.610	6.078	6.545
30	.451	.903	1.355	1.807	2.259	2.711	3.163	3.615	4.067	4.519	4.971	5.423	5.875	6.327

CUBIC FEET OF GAS CONSUMED.

NOTE.—Opposite the quantity of gas consumed, and under the number of grains of baric sulphate collected, will be found the number of grains of sulphur contained in 100 cubic feet of gas.

Sugg's Table for Ascertaining the Percentage of Sulphur.
Grains of Baric Sulphate collected on Filter.

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
10	20.338	21.694	23.050	24.406	25.762	27.118	28.474	29.830	31.186					
11	18.489	19.722	20.955	22.187	23.420	24.653	25.885	27.118	28.351	29.583	30.816			
12	16.949	18.079	19.209	20.338	21.468	22.598	23.728	24.858	25.988	27.118	28.248	29.378	30.508	
13	15.645	16.688	17.731	18.774	19.817	20.860	21.903	22.946	23.989	25.032	26.075	27.118	28.161	29.204
14	14.527	15.496	16.464	17.433	18.401	19.370	20.339	21.307	22.276	23.244	24.213	25.181	26.150	27.118
15	13.559	14.463	15.367	16.271	17.175	18.079	18.983	19.886	20.790	21.694	22.598	23.502	24.406	25.310
16	12.711	13.559	14.406	15.254	16.101	16.949	17.796	18.644	19.491	20.338	21.186	22.033	22.881	23.728
17	11.964	12.761	13.559	14.356	15.154	15.952	16.749	17.547	18.344	19.142	19.940	20.737	21.535	22.332
18	11.299	12.052	12.806	13.559	14.312	15.065	15.819	16.572	17.325	18.079	18.832	19.585	20.338	21.092
19	10.704	11.418	12.132	12.845	13.559	14.272	14.986	15.700	16.413	17.127	17.841	18.554	19.268	19.982
20	10.169	10.847	11.525	12.203	12.881	13.559	14.237	14.915	15.593	16.271	16.949	17.627	18.305	18.983
21	9.685	10.330	10.976	11.622	12.267	12.913	13.559	14.205	14.850	15.496	16.142	16.787	17.433	18.079
22	9.244	9.861	10.477	11.093	11.710	12.326	12.942	13.559	14.175	14.791	15.408	16.024	16.640	17.257
23	8.843	9.432	10.022	10.611	11.201	11.790	12.380	12.969	13.559	14.148	14.738	15.327	15.917	16.506
24	8.474	9.039	9.604	10.169	10.734	11.299	11.864	12.429	12.994	13.559	14.124	14.689	15.254	15.819
25	8.135	8.677	9.220	9.762	10.305	10.847	11.389	11.932	12.474	13.016	13.559	14.101	14.644	15.186
26	7.822	8.344	8.865	9.387	9.908	10.430	10.951	11.473	11.994	12.516	13.037	13.559	14.080	14.602
27	7.532	8.035	8.537	9.039	9.541	10.043	10.546	11.048	11.550	12.052	12.554	13.057	13.559	14.061
28	7.263	7.748	8.232	8.716	9.200	9.685	10.169	10.653	11.138	11.622	12.106	12.590	13.075	13.559
29	7.013	7.480	7.948	8.416	8.883	9.351	9.818	10.286	10.753	11.221	11.689	12.156	12.624	13.091
30	6.779	7.231	7.683	8.135	8.587	9.039	9.491	9.943	10.395	10.847	11.299	11.751	12.203	12.655

CUBIC FEET OF GAS CONSUMED.

NOTE.—Opposite the quantity of gas consumed, and under the number of grains of baric sulphate collected, will be found the number of grains of sulphur contained in 100 cubic feet of gas.

Sugg's Table for Ascertaining the Percentage of Sulphur.
Grains of Baric Sulphate collected on Filter.

	29	30	31	32	33	34	35	36	37	38	39	40	41
10													
11													
12													
13	30.247	29.055	30.024										
14	28.087	27.118	28.022	28.926	29.830	30.734	29.660	30.508					
15	26.214	25.423	26.271	27.118	27.966	28.813	27.916	28.713	29.511	30.309			
16	24.576	23.928	24.725	25.523	26.321	27.118	26.365	27.118	27.871	28.625	29.378	30.131	
17	23.130	22.598	23.352	24.105	24.858	25.612	24.977	25.691	26.404	27.118	27.832	28.545	29.259
18	21.845	21.409	22.123	22.836	23.550	24.263	23.728	24.406	25.084	25.762	26.440	27.118	27.796
19	20.695	20.338	21.016	21.694	22.373	23.050	22.598	23.244	23.890	24.535	25.181	25.827	26.472
20	19.661	19.370	20.016	20.661	21.307	21.953	21.571	22.187	22.804	23.420	24.036	24.653	25.269
21	18.724	18.489	19.106	19.722	20.338	20.955	20.633	21.223	21.812	22.402	22.991	23.581	24.170
22	17.873	17.686	18.275	18.865	19.454	20.044	19.773	20.338	20.903	21.468	22.033	22.598	23.163
23	17.096	16.949	17.514	18.079	18.644	19.209	18.983	19.525	20.067	20.610	21.152	21.694	22.237
24	16.384	16.271	16.813	17.355	17.898	18.440	18.252	18.774	19.295	19.817	20.338	20.860	21.381
25	15.728	15.645	16.166	16.688	17.209	17.731	17.576	18.079	18.581	19.083	19.585	20.087	20.590
26	15.123	15.065	15.568	16.070	16.572	17.074	16.949	17.433	17.917	18.401	18.886	19.370	19.854
27	14.563	14.527	15.012	15.496	15.980	16.464	16.364	16.832	17.299	17.767	18.234	18.702	19.170
28	14.043	14.026	14.494	14.961	15.429	15.897	15.819	16.271	16.723	17.175	17.627	18.079	18.531
29	13.559	13.559	14.011	14.463	14.915	15.367							
30	13.107	13.559	14.011	14.463	14.915	15.367							

CUBIC FEET OF GAS CONSUMED.

NOTE.—Opposite the quantity of gas consumed, and under the number of grains of baric sulphate collected, will be found the number of grains of sulphur contained in 100 cubic feet of gas.

Sugg's Table for Ascertaining the Percentage of Sulphur.
Grains of Baric Sulphate collected on Filter.

	42	43	44	45	46	47	48	49	50	51	52	53	54
10													
11													
12													
13													
14													
15													
16													
17													
18													
19	29.973	30.686											
20	28.474	29.152	29.830	30.508									
21	27.118	27.764	28.410	29.055	29.701	30.347							
22	25.885	26.502	27.118	27.734	28.351	28.967	29.583	30.200					
23	24.760	25.350	25.939	26.529	27.118	27.708	28.297	28.887	29.476	30.066			
24	23.728	24.293	24.858	25.423	25.988	26.553	27.118	27.683	28.248	28.813	29.378	29.943	30.508
25	22.779	23.322	23.864	24.406	24.949	25.491	26.033	26.576	27.118	27.661	28.203	28.745	29.288
26	21.903	22.425	22.946	23.468	23.989	24.511	25.032	25.554	26.075	26.597	27.118	27.640	28.161
27	21.092	21.594	22.096	22.598	23.101	23.603	24.105	24.607	25.109	25.612	26.114	26.616	27.118
28	20.338	20.823	21.307	21.791	22.276	22.760	23.244	23.728	24.213	24.697	25.181	25.665	26.150
29	19.637	20.105	20.572	21.040	21.507	21.975	22.442	22.910	23.378	23.845	24.313	24.780	25.248
30	18.983	19.435	19.886	20.338	20.790	21.242	21.694	22.146	22.598	23.050	23.502	23.954	24.406

CUBIC FEET OF GAS CONSUMED.

NOTE.—Opposite the quantity of gas consumed, and under the number of grains of baric sulphate collected, will be found the number of grains of sulphur contained in 100 cubic feet of gas.

Sugg's Table for Ascertaining the Percentage of Sulphur.
Grains of Baric Sulphate collected on Filter.

	55	56	57	58	59	60	61	62	63	64	65	66	67
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25	29.830	30.372											
26	28.683	29.204	29.726	30.247									
27	27.620	28.123	28.625	29.127	29.629	30.131							
28	26.634	27.118	27.602	28.087	28.571	29.055	29.539	30.024					
29	25.715	26.183	26.651	27.118	27.586	28.053	28.521	28.988	29.456	29.923	30.391		
30	24.858	25.310	25.762	26.214	26.666	27.118	27.570	28.022	28.474	28.926	29.378	29.830	30.282

NOTE.—Opposite the quantity of gas consumed, and under the number of grains of baric sulphate collected, will be found the number of grains of sulphur contained in 100 cubic feet of gas.

CUBIC FEET OF GAS CONSUMED.

WM. W. GOODWIN & CO.,

1012, 1014, and 1016 Filbert Street, Philadelphia,

MANUFACTURERS OF

Wet and Dry Gas Meters, Station Meters
(*Square, Cylindrical, or in Staves*), *Test and*
Show Meters:

**Pressure Registers, Vacuum and Pressure Registers, Pressure
Gauges, Test Gas-holders, all Sizes, Standard Cubic
Foot Measures, Stationary or Portable.**

All kinds of Apparatus for determining quantity of Sulphur and Ammonia in Coal Gas by Volumetric Analysis, Eudiometers, and Absorption Tubes. Also, all other Testing and Chemical Apparatus, of the most perfect description, relating to gas.

Photometrical Apparatus of every description.

Goodwin's Improved Bunsen-Letheby Electrical Photometer.—This instrument extinguishes the gas and candle, stops the meter and clock at any moment desired, either by time, gas, or candle. Patented Dec. 22, 1874.

Goodwin's Improved Lowe's Jet Photometer.—This instrument shows the candle power and pressure required for same on dial. Patented April 22, 1873; re-issued Jan. 26, 1875. All other candle power dials are infringements.

Goodwin's Electrical Photometer Balance for weighing candles *in situ*. Patented Jan. 12, 1875.

Goodwin's Density and Specific Gravity Apparatus for determinations by the Effusion Method. Patented Dec. 15, 1874.

Apparatus for Testing for Sulphur in Gas, as illustrated and described in "The Quantitative Estimation," &c.

Wright's Apparatus, Fig. 7, page 23.

Letheby's " Fig. 8, page 23.

Referees' " Fig. 9, page 24.

Valentin's " Fig. 10, page 25.

Flask (1), Fig. 11, page 30.

*Meter and Governor, Fig. 6, page 19.

Glass Measures, graduated (2), Funnels (6), 3 inches diameter.

Filter Stand (1), Beakers (6), Fig. 12, page 31.

Platinum Crucible and Cover, Fig. 11, page 30.

" Wire, 1 foot.

Bunsen Burner and Retort Stand, Fig. 11, page 30.

Pint Wash-bottle (1).

Porcelain Evaporating Dishes (2).

Glass Bottles Stoppered (2), wide mouths.

" " " for Acid Solutions (4).

" " " Engraved (3).

Pint Beaker, precipitating, and two Glass Stirrers.

Pipettes, 2 oz.

CHEMICALS.

Hydrochloric Acid, pure, $\frac{1}{2}$ lb. in stoppered bottle.

Nitric Acid, pure, 1 lb. in stoppered bottle.

Bromine, pure, 1 oz. in stoppered bottle.

Baric Chloride, pure, 1 lb. in stoppered bottle.

Nitrate of Silver, $\frac{1}{2}$ oz. in bottle.

Ammonia, pure, in stoppered bottle.

Ammonia, Carbonate, pure, in bottle.

Distilled Water, pure, in bottle (1 gallon).

Swedish Filter-paper, in quires.

STANDARD SOLUTIONS FURNISHED.

* Only one Meter and one Governor are required, if the two operations be simultaneously conducted.

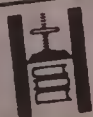
(See page 2 of cover for Ammonia Testing Apparatus.)



1012, 1014, 1016 FILBERT STREET, PHILADELPHIA.



HECKMAN
BINDERY INC.



NOV 91

N. MANCHESTER,
INDIANA 46962



LIBRARY OF CONGRESS



0 033 266 723.3